AGRICULTURE

The State of Agriculture in the San Juan Watershed

Are the Animas and San Juan Rivers Safe for Agricultural Uses?

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Introduction

The Animas and San Juan Rivers are significant sources of irrigation water in the arid southwestern United States. The San Juan watershed has been utilized as a water source for millennia (Aton and McPherson, 2000). It is an incredibly unique watershed, from its source water high in Colorado's San Juan Mountains to its impoundment at Lake Powell in Utah. The watershed has a rich history founded in decades of resource extraction, recreational use, and water supply. As with many water bodies in the U.S., the watershed also has rich cultural history and is a foundation of the region's heritage.

Local stakeholders have cited concern about using water from the Animas and San Juan Rivers. These concerns are largely related to health and safety regarding human consumption and beneficial uses of the water, and include, but are not limited to: the health and well-being of livestock; the safety of consuming livestock in the region; metal and pesticide loading in the watershed; risks to crops by uptake of metals; and the safety of corn pollen and associated river water for ceremonial purposes. The Animas and San Juan Rivers contain many diversion structures that redirect water from the main river in Colorado, New Mexico, Ute Mountain Ute, Southern Ute, Navajo Nation, and Utah to irrigation canals. The water diverted by the canals is utilized for municipal purposes, energy production, and agriculture.

Like most rivers across the U.S., the San Juan and Animas historically receive both natural and anthropogenic sources of pollutants. The natural geology of the upper watershed contains metal-laden rock that is constantly exposed to the atmosphere. Even before the presence of humans, it was likely that significant concentrations of metals occurred naturally in the region's waterways (Church et. al, 2007). Since the 1860's, humans have exacerbated natural metal levels in the watershed by extracting metals from ore deposits and altering the region's natural hydrology and geology (Newton et. al, 2017). The types and concentrations or "fingerprints" of metals vary in the watershed with changes in hydrology, geology, and elevation, and create unique signatures. Hundreds of abandoned mines in the upper Animas River contribute metals that adversely affect water quality. Metal loading contributions from the mines result in surface water pollution, causing the river to occasionally exceed screening levels for agricultural use (U.S. EPA, 2017). The sources of pollution alter the fingerprint of metals with different metal signatures observable in different reaches of the river. The diversity of metal signatures is associated with different metal sources, as well as varying biogeochemical cycling mechanisms in the watershed.

EPA conducted a literature review and compiled available data to evaluate existing research on and identify the concerns of stakeholders regarding the use of the Animas and San Juan Rivers for agricultural purposes. To frame the discussion, this report begins with a general history of agriculture in the watershed, including information about diversion projects, groundwater, and eutrophication in the watershed.

While metal concentrations within the river remain a top concern for agricultural and other users, water quality in the watershed can be affected by other inputs. Natural sediment deposition, agricultural runoff, uranium mining operations, dewatering, livestock, invasive species, septic systems, and stormwater runoff are all condition-based variables in the watershed. This report discusses how these factors inform the state of agriculture in the watershed.

Because the watershed's highly variable nature makes it a difficult to classify in its entirety, its characteristics are more easily understood using state and tribal boundaries. As such, the discussion of specific agriculture characteristics and available data is presented upstream to downstream through Colorado, Southern Ute tribal lands, New Mexico, Utah, and Navajo Nation tribal lands. The report also includes a focused discussion on data collected in association with the Gold King Mine (GKM) event, to evaluate potential risks to agriculture presented by the event. Finally, the data are summarized and coupled with a holistic perspective on agriculture in the region.

History of Agriculture in the San Juan Watershed

Human activity in the San Juan watershed has been dated back at least several thousand years (Aton and McPherson, 2000). Over that span, human societies have extensively modified the landscape to increase agricultural productivity in the region. This section describes general metal loading trends, modern agricultural diversions in the watershed, the use of groundwater for irrigation, and eutrophication in the watershed. This discussion informs the subsequent development of the state of agriculture in each jurisdiction of the watershed.

Before discussing agriculture characteristics by state and tribe, it is important to understand the general transport and distribution of metals within the watershed. Metal loading in the watershed is typically highest during spring, when run-off conditions are approaching peak flow, as high discharges of water displace metal deposits in the upper watershed (U.S. EPA, 2016). The concentrations of metals vary drastically throughout the watershed. Runoff in the Animas headwaters distributes a different suite of metals than those observed in the San Juan and its tributaries. Due to the history of mining in the watershed, many studies have been conducted to determine the sources of metals, resulting in a fingerprinting approach of metal loading to help determine the origin of the pollutants.

Levels of metals and other pollutants can be compared to screening standards, which are established for different water uses. Agricultural screening standards are used to compare observed levels of pollutants from samples to established thresholds of safety for agriculture. The data suggest that specific events can create short-term metal exceedances to agricultural screening standards. However, exceedances also occur occasionally in the watershed, even during periods of low flow, due to historical background contamination (U.S. EPA, 2016).

Groundwater for Agriculture Use

Groundwater in the San Juan River watershed has historically been impacted by both agricultural practices and extraction industries (EPA, 2016; Church et al., 2007). In some areas of the watershed, water used for irrigating croplands can leach metals and minerals from the soil as it percolates back into groundwater aquifers. For example, groundwater monitoring efforts in the La Plata basin have shown that irrigated waters have increased the salt content of groundwater sources in the basin (BLM, 1996). Along the Animas River between the New Mexico border and Farmington, the water table is generally highest at the end of irrigation season in October, suggesting that irrigation water communicates with groundwater over the course of the season from March to October (Mamer, 2018). As discussed in the New Mexico section below, a recently completed New Mexico Bureau of Geology and Mineral Resources study identified seasonal changes in groundwater quality and the need for additional studies (Newton et al., 2017).

Studies have been conducted to investigate how mining in the region has the potential to effect groundwater. Although groundwater around the river basin typically flows toward the river, suggesting

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that communication of metals from the river to groundwater wells is unlikely, the safety of groundwater for irrigation use is a concern for residents (U.S. EPA, 2016). A study conducted by Mamer in 2018 assessed the potential for metal uptake in crops irrigated from groundwater sources. The authors recommended that residents refrain from drawing irrigation water from groundwater wells within 300 feet of the river in the case of a mine release event, specifically in the communities of Inca and Cedar Hill, NM. Several other studies have suggested that groundwater quality was not impacted by metals releases from the upper watershed (Newton et. al, 2017; U.S. EPA, 2016). EPA conducted a study during 2016, assessing the transport and fate of metals released from the GKM event in the Animas and San Juan Rivers. The study concluded that concentrations of metals in well-water samples after the contaminant plume had passed through the river system did not exceed federal drinking water standards, which are more stringent that agricultural standards (U.S. EPA, 2016).

Eutrophication and Impairments in the San Juan Watershed

For both the Animas and San Juan River watersheds, agricultural runoff from nonpoint-sources represents a significant source of nutrients, specifically nitrogen- and phosphorous-containing compounds (May, 2018). Contributions of nutrients and fecal coliform may be associated with agricultural inputs. Specifically, nutrients associated with fertilizing practices and fecal coliform from livestock waste can be mobilized by stormwater runoff and contribute to loads in the watershed.

Because nutrients on the lower Animas River occasionally exceed New Mexico state water quality standards, some studies have been conducted in the state. The results of those studies are discussed in the New Mexico section of this report.

Diversions in the Watershed

Numerous irrigation diversions on the Animas and San Juan Rivers extract water for agriculture use. The largest of these projects are sited at Navajo Lake, including the Navajo Indian Irrigation Project (NIIP), San Juan-Chama Diversion, and the Navajo-Gallup Water Supply Project. Navajo Lake is a reservoir located on the San Juan River near the Colorado/New Mexico border, and upstream of the confluence with the Animas River. Navajo Lake receives source water from areas in the upper San Juan River Basin which have been impacted by legacy mining. Navajo lake is listed as impaired for fecal coliform and sedimentation/siltation (NMED, 2005).

Diversions may distribute metals and other contaminants from the watershed to agricultural watering systems. This exposure pathway remains a primary concern for local communities who use river water for irrigation or consume crops and livestock grown with water from the diversions.

The largest diversion projects in the watershed, all of which transport water from Navajo Lake, are summarized below.

Navajo Indian Irrigation Project (NIIP)

The Colorado Plateau is an arid region and although the lands are fertile, water is required water to make them productive. Constructed by the Bureau of Reclamation (BOR) in 1977, the NIIP is the largest Native American owned and operated business in the United States. The NIIP designed to transport water from Navajo Lake and distribute it to tribal lands (Glaser, 1998a).

Snowmelt and runoff in the San Juan Mountains provide much of the source water for the NIIP, which distributes water through a complex network of pipes and channels to Navajo Nation farmlands operated by Navajo Nation Agricultural Products Industry (NAPI). The NIIP system is authorized to distribute 508,000 acre-feet of water to NIIP lands annually. The NIIP is the largest agricultural user of water in the San Juan watershed.

San Juan-Chama Diversion

The San Juan-Chama project diverts water from the San Juan River drainage to the Rio Grande basin. Completed in 1976, the project provides approximately 110,000 acre-feet of water to New Mexico per year (Glaser, 1998b).

Navajo-Gallup Water Supply Project

Although not yet completed, the goal of this project is to provide a reliable municipal and industrial water supply from the San Juan River to approximately 250,000 people in the eastern section of the Navajo Nation, southwestern portion of the Jicarilla Apache Nation, and the city of Gallup, New Mexico (U.S. Department of the Interior, 2009). The proposed project would divert an estimated 37,764 acre-feet of water per year from the San Juan River. Although the project does not currently involve agriculture, it has not been completed and water uses may be re-allocated.

Additional Agriculture Diversions in the Watershed

The lower Animas River and San Juan Rivers contain a number of smaller water diversions; however, there is limited information on which of these diversions are used for agriculture. Some diversions are specifically identified for agricultural uses, but it is possible that most diversions are used in some capacity for agriculture or crop watering. There are also water intake structures that pull water for irrigation, but their locations have not been identified in previous studies.

The literature review identified 39 diversions in the watershed, as shown below in Figure 1 (Lyons, 2016). Six diversions were identified on the upper San Juan between Navajo Lake and Farmington. Of the 39 diversions identified, there are 23 diversions identified on the Animas and San Juan Rivers used specifically for agricultural purposes (Lyons, 2016).

Irrigation diversions operate at different periods of the year to provide their users with water, but typically operate between mid-March and mid-October (Mamer, 2018). Crops grown in the watershed include corn, alfalfa, wheat, oats, beans, potatoes, and others. Livestock in the area is primarily comprised of cattle. Open pasture and fallow agriculture fields also exist throughout the region. The majority of agriculture occurs south of Farmington on NAPI farms, on Southern Ute tribal lands southeast of Durango, and along the Animas River between the Colorado border and Farmington.

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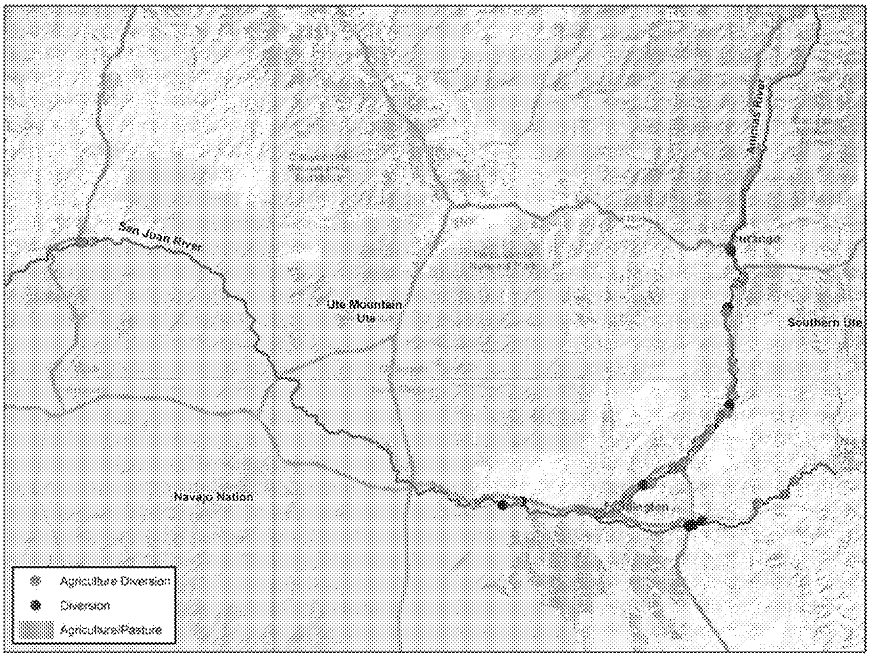
*Figure [SEQ Figure * ARABIC]. Water Diversion Structures and Agricultural Lands in the San Juan Watershed*



Colorado

The Animas River in Colorado begins as a series of high gradient tributaries at altitudes above 12,000 feet that drain a historically active mining region. The Animas River in Silverton is affected by metals from the Bonita Peaks Mining District, which consists of 48 historic mines. Hundreds of other abandoned mines exist in the greater Silverton region (EPA, 2016). Extensive mining in this area began shortly after the Brunot Agreement was formalized between the Ute Indian Tribe and the United States government in 1873. The last active mine in the area (Sunnyside) was closed in 1991 (Church et. al, 2007). As the Animas River reaches Durango, it generally slows and widens to the New Mexico border in a semi-desert sage brush scrubland (Animas Watershed Partnership, 2011). Near the New Mexico state line, the Animas is joined by the Florida River within Southern Ute lands.

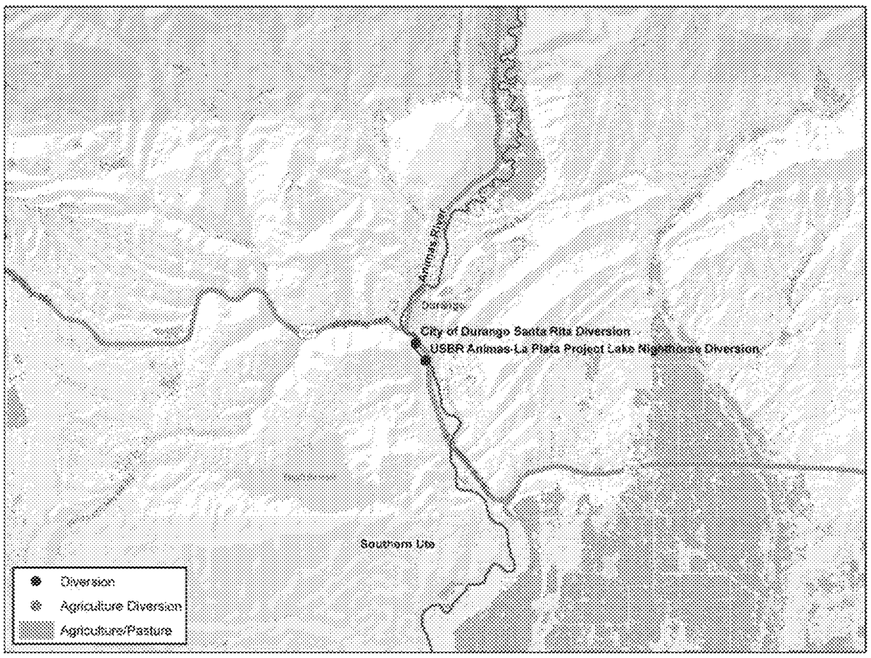
In addition to historic pollutant contributions from hard rock mining in the upper watershed, numerous other impairments exist along the course of the Animas River in Colorado. Upstream of Durango, there are large impacts from historical and current in-stream mining (Animas Watershed Partnership, 2011). Wildfires such as the 2018 416 fire which occurred in the Hermosa Creek drainage north of Durango also impact water quality when precipitation create debris and mud flows that can enter the river (Mountain

Studies Institute, 2018). In Durango, nutrients introduced to the river from the Hermosa Sanitation District, leaking septic systems, and golf courses and lawns have contributed to eutrophication (Animas Watershed Partnership, 2011). Downstream of Durango, improper grazing practices, sand mining and bank hardening, all impact water quality (Animas Watershed Partnership, 2011).

Numerous entities routinely monitor the Animas River within Colorado, including Colorado Department of Public Health (CDPHE), United States Geological Survey (USGS), Colorado Parks and Wildlife (CPW), and non-profit organizations such as the Mountain Studies Institute. These efforts have created a robust data set documenting the history and presence of metals in the watershed.

This research effort identified two water diversion structures along the Animas River in the state of Colorado (Lyons, 2016). While the two diversions were not identified as being used for agriculture, it is possible that they are used for irrigation in some capacity (Figure 2). Agricultural lands and practices are present within the corridor along the Animas river north of Durango, however, the source of water used for irrigation could not be identified.

*Figure [SEQ Figure * ARABIC] Water Diversion Structures and Agricultural Lands on the Animas River in Colorado*



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Southern Ute

The Animas River passes onto Southern Ute tribal lands south of Durango, Colorado, which continue to the New Mexico border. Southern Ute lands along the Animas exist solely within Colorado. The portion of the Animas River watershed that runs through Southern Ute territory is largely characterized by semi-arid, lower elevation mesas and plateaus with average annual precipitation ranging from 10 to 16 inches (Natural Resources Conservation Service, 2010). Vegetation largely consists of two needle pinyon, Utah juniper, and big sagebrush. Cropland represents a significant land use in this reach of the Animas River, and soil and precipitation limitations require irrigation on a vast majority of agricultural lands.

Water quality in the Southern Ute reach of the Animas River is impacted by the same influences as those described for Colorado. No unique influences were identified on this reach of the river.

Six diversions were identified on the Animas River within Southern Ute territory, five of which were identified as being used for agriculture (Figure 3). Information regarding the periods of operation and types of crops these diversions serve is limited. Agriculture occurs primarily to the east of the Animas River.

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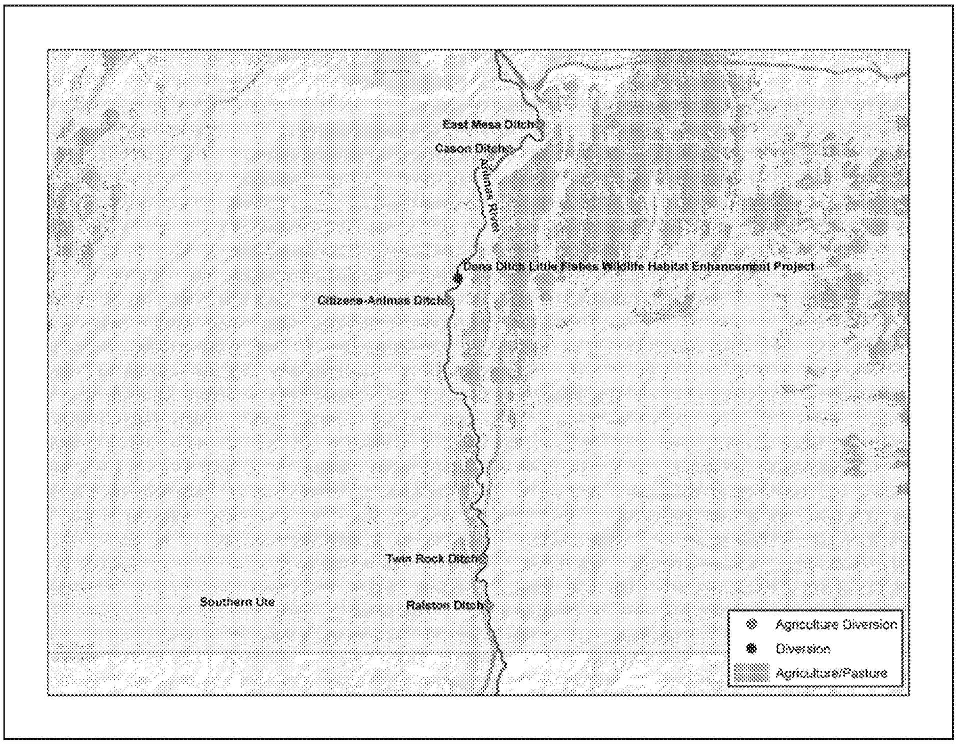
*Figure [SEQ Figure * ARABIC] Water Diversion Structures and Agricultural Lands on the Animas River on Southern Ute Tribal Lands*



New Mexico

The Animas River in New Mexico flows through Farmington to its confluence with the San Juan River. As the Animas River in New Mexico slowly decreases in elevation, its average annual precipitation regimes decline, and it transitions from mixed grass plains to a shrub-grassland matrix (Natural Resources Conservation Service, 2010). The San Juan River also receives input from the La Plata River in the vicinity of Farmington.

The San Juan River in its upstream reaches prior to reaching Farmington has different characteristics from the downstream reaches. Because the river receives its flow from the bottom of Navajo Lake, the upper reaches of the San Juan River are colder and less turbid than the lower reaches.

There are seventeen diversions on the Animas River between the New Mexico border and Farmington. Approximately 8% of land use along the Animas River from the Colorado-New Mexico border and Farmington is characterized as agricultural, with alfalfa representing the major crop in the region (NMED, 2005; Colorado River Water Users Association; n.d.). Agriculture in this region has been the subject of study because it is a significant land use in the area (Newton et. al, 2017).

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Downstream of Farmington, the river borders New Mexico to the north and Navajo Nation to the south. The San Juan River through this reach is dominated by shrubland and herbaceous grasslands (Natural Resources Conservation Service, 2002). The geology is largely characterized by Mancos shale, and oil and gas development in this portion of the watershed is extensive (Fassett, 2014). Metals in soil and surface water in this region are historic but are characterized by a different fingerprint than those in the upper watershed.

Groundwater in the Animas river valley is extracted for agricultural uses. The New Mexico Bureau of Geology and Mineral Resources recently completed a groundwater study to evaluate how groundwater wells in the watershed communicated with the Animas alluvial aquifer. The study found that metals following the GKM event were not observable in groundwater wells in New Mexico along the Animas River and identified the need for further research (Mamer, 2018). In addition, the study found elevated levels of metals in groundwater wells used for irrigation. The report also noted that local farmers observed changes in groundwater quality seasonally, with some consistency. Reductions in water quality are observable following spring runoff, when metals transported from the Animas headwaters interact with the Animas alluvial aquifer, increasing the amount of metals in the water (Newton et al., 2017).

A study conducted by New Mexico State University (NMSU) investigated whether water sourced from groundwater and irrigation diversions in the Animas River affected agricultural crop composition. While the study focuses on the effects of the GKM event, its findings are informative to the current state of agriculture in the region. The report states that "[w]hile the U.S. Environmental Protection Agency (EPA) and the New Mexico Environment Department (NMED) have both taken the position that, in all likelihood agricultural crops are safe, there remains potential that contaminated sediments from these rivers and ditches may have been broadcast to crops and fields by irrigation. Other than slightly elevated soil arsenic, none of the metals appear to have a significant impact on the region (Jha et. al 2018)." Another NMSU study conducted in San Juan County found that "the average concentration of total As and Mn exceeded the guideline value (As-7.07 ppm [parts per million], Mn-180 ppm) specified by NMED at certain hotspots that were identified for pasture (As-7.19 ppm, Mn-874.92 ppm), alfalfa (As-6.92 ppm, Mn-545.04 ppm) and vegetable (As-7.13 ppm, Mn-312.84 ppm) fields. Other elements of concern were below the EPA-RSL (Jha et al., 2018b)."

As previously mentioned, eutrophication in New Mexico has also been the subject of study. In 2002, low flow conditions in the Animas River exacerbated extensive algal blooms (May, 2018). As a result of the algal blooms, nutrient loadings into the watershed were identified as an emerging concern. In an attempt to reduce nutrient loadings to the Animas River watershed, the State of New Mexico established (i) a Total Maximum Daily Load (TMDL) for the Estes Arroyo-San Juan River reach of the Animas River for nutrients in 2006, and (ii) a second TMDL for the Southern Ute Indian Tribe (SUIT)-San Juan River reach for total phosphorous and fecal coliform in 2013 (Mountain Studies Institute, 2016). While efforts to reduce issues associated with agricultural runoff and nutrient influx into the Animas and San Juan River watershed are ongoing, challenges persist. Segments of the Animas River in New Mexico remain on the New Mexico 303(d) list for nutrient eutrophication and total phosphorous (Animas Watershed Partnership, 2014). Additionally, since 2010, the lower Animas has exceeded New Mexico state water quality criteria (WQC) and TMDL targets for phosphorous and nutrients/eutrophication, among other parameters (Mountain Studies Institute, 2016). Dewatering activities such as removal of river discharge for agricultural uses can exacerbate eutrophic conditions in the watershed.

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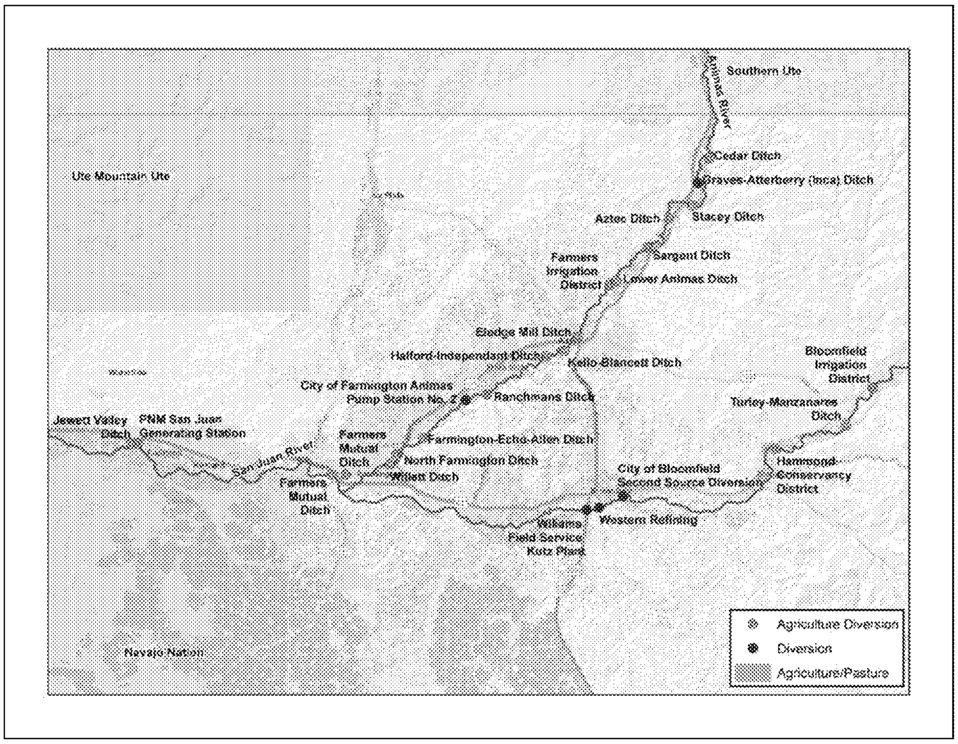
Twenty-five diversions were identified along the Animas and San Juan Rivers in New Mexico (Figure 4), 19 of which appear to be used specifically for agricultural purposes (Lyons, 2016). The majority of these diversions occur between the Colorado border and Farmington, NM on the Animas River. Two of these diversions occur on the San Juan River below Farmington, and six occur on the San Juan upstream of the Animas confluence.

*Figure [SEQ Figure * ARABIC] Water Diversion Structures and Agricultural Lands on the Animas and San Juan Rivers in New Mexico*



Utah

The San Juan River crosses into Utah in the Four Corners area and is bordered to the south by the Navajo Nation until it reaches Lake Powell. The characteristics of the river in these reaches are drastically different from the river's headwaters, meandering through sandstone canyons flanked with invasive Russian olive and Saltcedar (Bassett, 2015). The river is characterized by a low gradient and high turbidity. The lower San Juan River has a long history of resource extraction, specifically oil and natural gas.

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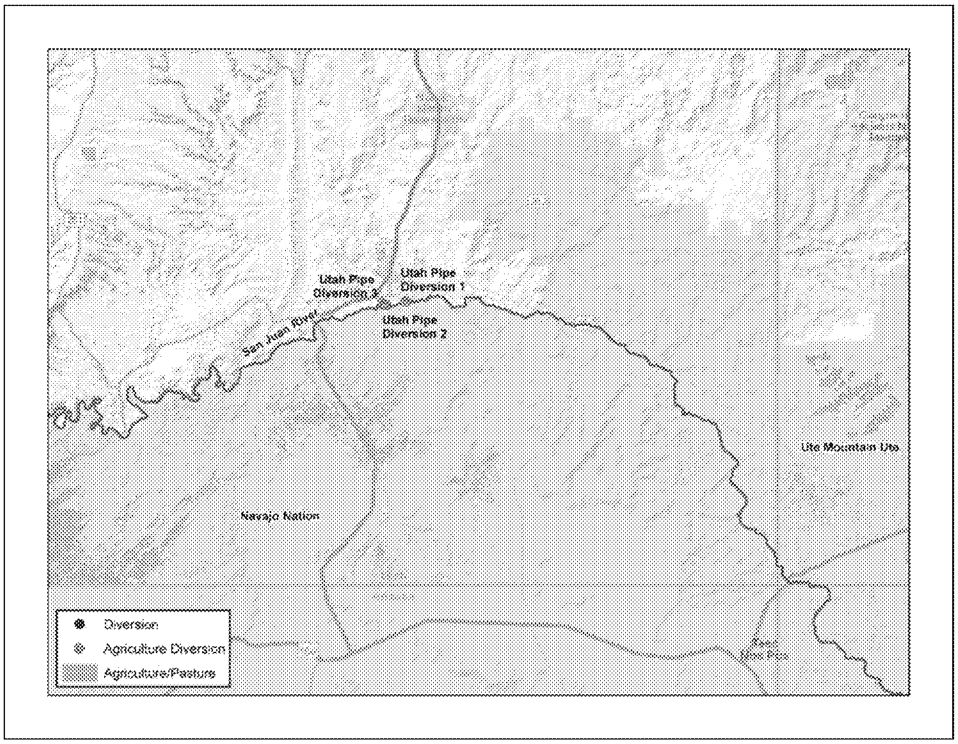
Inputs to the San Juan River through this area includes seasonal flow from Montezuma Creek, McElmo Creek, Chinle Wash, and numerous small seasonal and ephemeral tributaries , which can significantly impact the turbidity of the river.

Utah Department of Environmental Quality (UDEQ) has performed two studies related to agricultural uses of the San Juan River. The first was an agricultural risk assessment for the San Juan River and Lake Powell, and the second was a comparison of Agency for Toxic Substances and Disease Registry (ATSDR) screening levels to the GKM plume in Utah. The first study concluded that "[b]ased on the evaluation of risks associated with direct human exposure to SJR [San Juan River] water and sediment, agricultural exposure pathways, and potential accumulation of metals in soil, there are no immediate risks to human health or agricultural receptors" (Tetra Tech, 2018). The second study observed no exceedances for dissolved metal concentrations, for agricultural uses or livestock water for (UDEQ, 2015).

Overall, fewer agricultural diversions exist on the lower San Juan River than the upper San Juan or the Animas River. Only three agricultural diversions were identified, all in the vicinity of Bluff, Utah (Figure 5). Overall, less agriculture is observable along the San Juan river in Utah than in New Mexico.

*Figure [SEQ Figure * ARABIC] Water Diversion Structures and Agricultural Lands on the San Juan River in Utah*

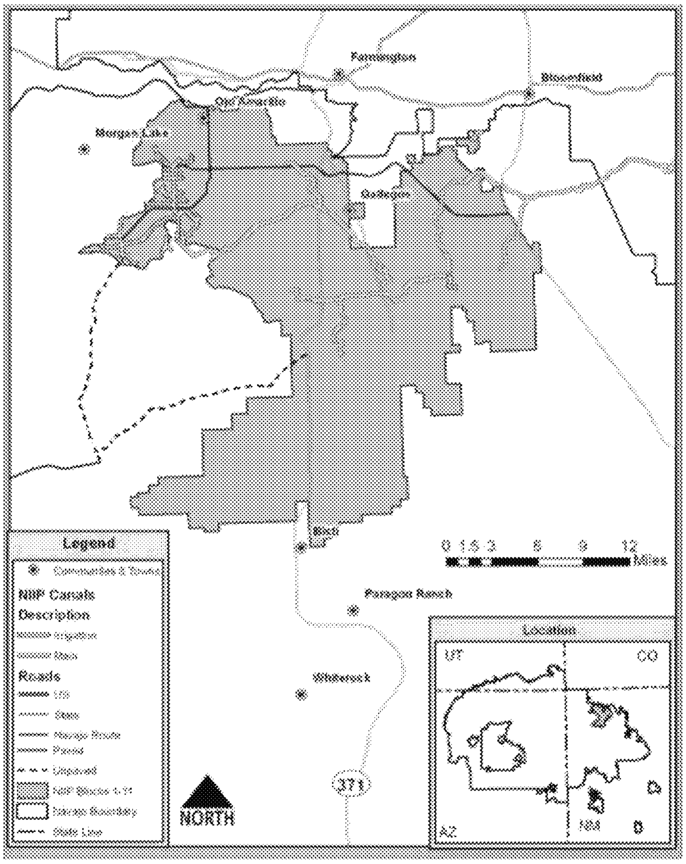


Navajo Nation

Beginning downstream of Farmington, New Mexico, the Navajo Nation borders the San Juan River along its southern bank to the confluence with Lake Powell. Between Kirtland, New Mexico, and Shiprock, New Mexico, the San Juan River crosses onto Navajo Nation lands on both the north and south. As the river passes through the Four Corners area, it remains solely on Navajo Nation lands to the vicinity of Bluff, Utah. From Bluff to its confluence with Lake Powell, the river is bordered by Utah on the north and Navajo Nation on the south. The San Juan River receives input from Chaco Wash in the vicinity of Shiprock, and Mancos Creek in the Four Corners area. The characteristics of the river in Navajo Nation are that of the previously described states of New Mexico and Utah.

As the river passes onto exclusively Navajo Nation lands, no diversions for agriculture were identified through literature review. Three diversions were identified on the portion of the river between Farmington and Shiprock (Figure 7), two of which are for agricultural uses. Large farming developments on Navajo Nation rely on San Juan River water. However, this water is sourced from the upstream irrigation projects such as NIIP, as shown below in Figure 6. The NIIP roughly parallels the river from Navajo Lake to farming areas operated by NAPI, which is located southwest of Farmington.

*Figure [SEQ Figure * ARABIC] Navajo Indian Irrigation Project (NIIP)*[1]



Despite sourcing water upstream from Navajo Lake, agriculture is a significant cultural and economic presence on Navajo Nation. The San Juan River is also a spiritual source of water for Navajo peoples (Francis, 2018). Navajo ceremonies use San Juan River water to grow the plants needed to perform rituals. When use of agriculture diversions stopped following the GKM event, plants used for ceremonial purposes died (Francis, 2018).

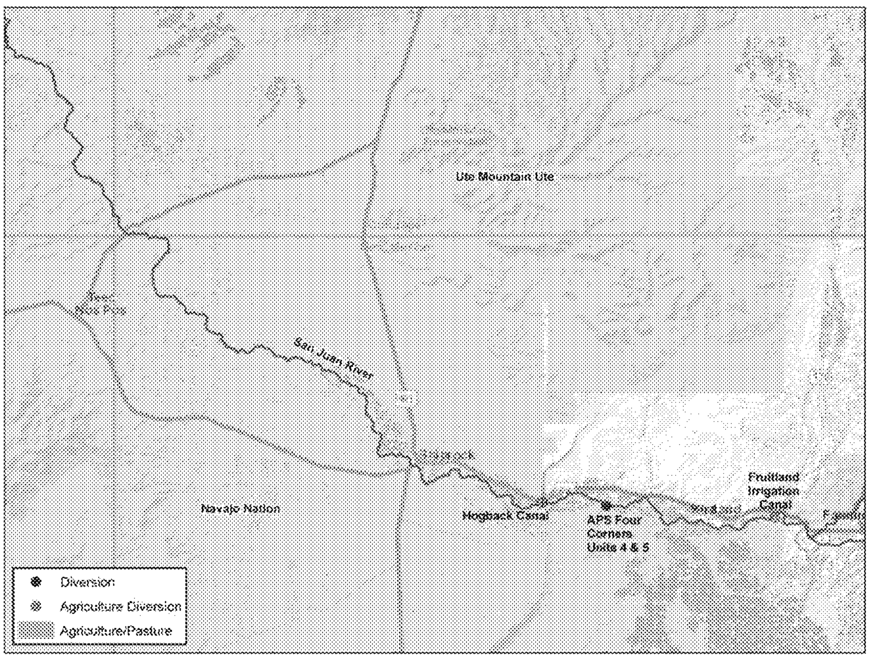
Following the GKM event, a study was performed on Navajo Nation to determine the concentration levels of contaminants from the spill. The results are forthcoming but illustrate ongoing concern in the Navajo community about contamination from the spill (Gilbert, 2018). In August 2017, an additional study was conducted to evaluate the impact of heavy metal contamination from historical mining on Navajo Nation agriculture systems. Canal water, canal sediment cores, field sediment cores, and mature

[1] Reprinted from *Water Resource Development Strategy For the Navajo Nation*, July 2011, retrieved from [HYPERLINK "http://www.frontiernet.net/~nndwr_wmb/PDF/NNWaterStrategyDraft_7-13.pdf"].

corn plants were collected and analyzed with mass spectrometry for metals (Froyum and Ingram, 2018). Results are forthcoming.

Water quality standards revision were recently proposed by Navajo Nation. All previous water quality studies were done in comparison of U.S. EPA's 1972 Water Quality Criteria. Additional comparisons of revised standards to collected data may alter previous report findings. Specifically, Navajo Nation claims that the rationale for adopting U.S. EPA's 1972 Water Quality Criteria for agricultural uses and livestock watering is unclear. Specifically, Navajo Nation finds that the calculations used to create the 1972 criteria are not provided, and that rationale for the numeric standards are lacking (Tetra Tech, 2018). A report commissioned by Navajo Nation found that utilizing a risk-based approach would support different water quality criteria. Specifically, a risk-based approach assesses sources, transport mechanisms, points of exposure, exposure pathways, and intermediate receptors of importance of the river to the Navajo Nation. For additional information regarding the risk-based approach, refer to Appendix A.

*Figure [SEQ Figure * ARABIC] Water Diversion Structures and Agricultural Lands on the Animas River on Navajo Nation Tribal Lands*



Gold King Mine Event

On August 5, 2015, approximately three million gallons of mine water were inadvertently released from the Gold King Mine near Silverton, Colorado, into Cement Creek, a tributary of the Animas River (Tetra Tech, 2018). The release flowed downstream through the Animas and San Juan Rivers as an orange-tinted plume before eventually settling in Lake Powell on August 14, 2015. Following the event, the agricultural community and local stakeholders raised concerns regarding potential contamination to crops and livestock from use or irrigation water. As previously discussed, hard rock mining in the Animas river headwaters and uranium mining on the San Juan River contributed to concerns about water quality. The GKM event raised additional concerns and prompted additional studies by federal agencies, local states and tribes, and community stakeholders. These studies are discussed below to evaluate if GKM had the potential to effect agricultural systems.

Most irrigation ditches within the state of New Mexico and Navajo Nation were closed immediately after the GKM event, reducing the chance that the passing plume of metals from GKM could enter irrigation systems (EPA, 2017). However, personnel at the state of New Mexico noted that not all irrigation structures could be closed due to inoperable head gates and other difficulties preventing intake closure.

Following the GKM event, communities restarted agricultural diversions at different times, though actual timing is undocumented (Xiaobo, 2018). Although there is some variability between operational periods, the majority of diversions are active during the period from mid-March to mid-October (Mamer, 2018). Although it is unclear which diversions were in operation following the GKM event, some diversions may have been in operation during spring runoff in 2016. During 2016 runoff, the majority of remaining metals from the GKM event were transported downstream to Lake Powell.

Following the GKM event, multiple studies evaluated whether legacy metals from the GKM had the potential to impact irrigation water used for agricultural purposes. These studies suggested that agricultural exposure pathways posed no immediate risks to human health or agricultural receptors (Tetra Tech, 2018; U.S. EPA, 2016; Jha et. al 2018). The contaminant plume created by the GKM event likely bypassed irrigation systems and deposited in the Animas River before the confluence with the San Juan (U.S. EPA, 2016). Metals were then transported via runoff to Lake Powell during the spring of 2016 (U.S. EPA, 2016). However, concerns regarding the current condition of the watershed with respect to agricultural uses persist, and can be broadly grouped as follows:

- Did the contaminant plume from the GKM event impact crops irrigated with water from the rivers?
- Did the contaminant plume from the GKM event impact livestock watered by irrigation systems?
- Are legacy metals from the GKM event still in the watershed and do they have the potential to impact crops or livestock being irrigated with water from the rivers?
- Did the GKM event influence groundwater used for irrigating crops?

By using a "fingerprinting" approach of the metals from GKM, research shows that the plume moved quickly through the rivers, depositing metals as it went, primarily in the Animas. Runoff in the spring of 2016 mobilized the remaining metals and deposited them in Lake Powell (U.S. EPA, 2016). By 2017, metal concentrations during runoff had returned to historic lows (Sullivan et. al., 2018).

To assess if risks to agriculture were introduced by the GKM release, various data sets can be compared with agricultural screening levels and livestock watering standards. Because metal concentrations were highest during the GKM plume and spring 2016 runoff, these periods represent the highest risk for agriculture in the watershed. The data also suggest that GKM metals had passed through the river system by 2017 (EPA, 2016). Therefore, the discussion on if the GKM presented threats to agriculture is grouped into three questions:

1. How do metal concentrations in the contaminant plume compare to agricultural screening standards?
   Sub question: Can observed metal concentrations within the contaminant plume be correlated to irrigation intake locations as the plume moved down the watershed?
2. How do metal concentrations during high-flow conditions compare to agricultural screening standards?
   Sub question: Can metal concentrations during high-flow rates be paired with the locations of irrigation intakes to show what metal concentrations were observed in Spring 2016 runoff or other high-flow conditions?
3. What impact did the GKM event have on livestock through livestock watering?

Comparing observed metal concentrations and screening values during high-flow and plume periods identifies a "worst case scenario." The responses below present quantitative comparisons and a qualitative summary of available literature to demonstrate this worst case scenario.

Question One: How do metal concentrations in the contaminant plume compare to agricultural screening standards?

There are two options available to compare the plume from the GKM event with agricultural screening standards. The first is to compare post-release data collected by EPA with agricultural screening standards, regardless of the location of an agricultural intake. The second and more difficult approach is to attempt to align data collected during the GKM event with the location of agricultural intakes.

UDEQ commissioned a study comparing agricultural screening levels with samples taken as close to the plume as possible. The results are presented below.

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*Figure [SEQ Figure * ARABIC] Comparison of Livestock Water, Irrigation Water (Short-Term), Irrigation Water (Long-Term) Screening Values to UDEQ Sampling Results*[2]

				Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Molybdenum	Nickel	Potassium	Selenium	Silver	Sodium	Thallium	Vanadium	Zinc
Livestock Water				5,000	(blank)	200	(blank)		50	500	1,000		500	(blank)	100	250,000	(blank)	10	(blank)			50	(blank)	1000000	(blank)	100	25000
Irrigation Water Short-term NAS, 1972				5,000	(blank)	100	(blank)		10	(blank)	100	50	200	5000		(blank)	200	(blank)	10	200	(blank)	20	(blank)			100	2000
Irrigation Water Long-term NAS, 1972				20,000	(blank)	2,000	(blank)		50	(blank)	1,000	5,000		20,000	10,000	(blank)	10,000	(blank)	50	2,000	(blank)	20	(blank)			1000	10000
				(blank)		100	(blank)		10	(blank)	100	(blank)	200	(blank)	100	(blank)						50	(blank)				
Monitoring Location	Site Description	Collection Date	Collection Time	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	mg/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
4953000	San Juan R @ Mexican Hat US163 Xing	8/8/2015	5:40 PM	264	0	0	308	0	0	49.2	0	0	3.95	144	0	5,750	2.81	0	3.15	0	4,150	0	0	62,600	0	0	14.2
		8/10/2015	11:53 AM	325	0	0	299	0	0	44.6	0	0	2.95	140	0	7,840	2.55	0	2.43	0	3,410	0	0	43,600	0	7.59	17.6
		8/10/2015	4:44 PM	149	0	0	265	0	0	44.2	0	0	2.48	0	0	7,670	0	0	2.63	0	3,350	0	0	41,800	0	6.67	18.5
4953250	San Juan R @ Sand Island	8/8/2015	4:19 PM	214	0	0	294	0	0	73.7	0	0	3.88	104	0	9,240	2.55	0	3.3	0	4,110	0	0	51,200	0	0	19
		8/10/2015	11:15 AM	124	0	0	192	0	0	53.2	0	0	2.07	0	0	8,400	0	0	2.38	0	2,860	0	0	28,400	0	0	13.7
		8/10/2015	3:58 PM	108	0	0	184	0	0	46.4	0	0	0	0	0	7,830	0	0	2.26	0	2,670	0	0	30,600	0	0	13.2
4953990	San Juan R @ Town of Montezuma	8/8/2015	2:54 PM	138	0	0	223	0	0	71.5	0	0	2.72	0	0	9,920	0	0	2.62	0	3,840	0	0	43,500	0	0	21
		8/10/2015	10:13 AM	218	0	0	262	0	0	49.9	0	0	3.24	144	0	7,700	3.22	0	2.03	0	2,690	0	0	32,100	0	0	17.3
		8/10/2015	2:58 PM	0	0	0	300	0	0	48.6	0	0	2.48	0	0	7,350	0	0	2.32	0	2,590	0	0	31,800	0	0	14.6
4954000	San Juan R @ US160 Xing in CO	8/8/2015	1:23 PM	217	0	0	222	0	0	51.5	0	0	2.24	0	0	7,850	2.94	0	0	0	2,960	0	0	32,200	0	4.86	15.3
		8/9/2015	12:02 PM	258	0	0	274	0	0	50.6	0	0	2.48	119	0	6,860	2.89	0	2.01	0	2,610	0	0	28,500	0	0	18.5
		8/9/2015	9:02 PM	329	0	0	341	0	0	46	0	0	3.47	198	0	8,300	4.14	0	0	0	2,380	0	0	30,300	0	0	15.4
		8/10/2015	9:11 AM	172	0	0	233	0	0	44.6	0	0	3.21	103	0	8,010	0	0	2.03	0	2,510	0	0	34,100	0	0	19.7
		8/10/2015	2:06 PM	1,050	0	0	220	0	0	44.2	0	0	3.35	732	0	8,020	12.8	0	0	0	2,720	0	0	35,100	0	0	18

	No Exceedence		Background
	Above Screening Level		Potential Plume Presence
			Plume Presence Likely

[2] (UDEQ, 2015)

As shown in Figure 8, no exceedances for livestock, or short/long term irrigation water standards were observed as part of this study. Three irrigation diversions were identified in the vicinity of the study. The study site "Montezuma Creek" is the site closest to these three diversion intakes, which are located close to each other in Bluff, Utah.

EPA responded within hours of the GKM event, sampling plume conditions as it moved downstream. Table 7-4 of EPA's *Analysis of the Transport and Fate of Metals Released from the Gold King Mine in the Animas and San Juan Rivers* report illustrates how the plume had the greatest effect in the Animas River before reaching the Aztec, New Mexico area. This suggests that the effects of the passing plume on agriculture diminished substantially downstream of Aztec and corroborates the UDEQ dataset. Figure 9 shows the number of hours in which exceedances were observed upstream of Aztec New Mexico.

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*Figure [SEQ Figure * ARABIC] EPA's Analysis of the Transport and Fate of Metals Released from the Gold King Mine in the Animas and San Juan River[3]*

Table 7-4. Hours Exceeding Magnitude Component of Agricultural Use Criteria During Passage of the Gold King Mine (GKM) Plume in the Animas and San Juan Rivers. Water concentrations estimated by the empirical model were screened using the criteria from Table 7-1 appropriate to the site, based on location (indicated at bottom of column). Definition and naming of agricultural criteria varies by state. Table values are color coded based on relative difference within spreadsheet values to assist the reader in finding values in the table; colors are not based on importance of hours.

Agriculture / Irrigation	Hours At or Above Criteria During Passage of GKM Plume										
	Animas River						San Juan River				
	Below Silverton (RK 16.4)	Bakers Bridge (RK 64)	Durango (RK 94)	NAR06 (RK 132)	Aztec (RK 164)	Farmington (RK 190)	Farmington (RK 196)	Shiprock (RK 246)	Four Corners (RK 296)	Bluff (RK 377)	Mexican Hat (RK 421)
Aluminum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Antimony	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Arsenic	8.00	4.50	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Barium	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Beryllium	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cadmium	6.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chromium	2.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cobalt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Copper	10.75	6.75	5.25	3.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iron	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lead	13.75	36.75	23.50	24.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Manganese	13.75	37.25	15.75	15.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Molybdenum	2.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nickel	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Selenium	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Silver	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Thallium	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Vanadium	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Zinc	6.75	2.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Criteria Used:	CO	CO	CO	CO	NM	NM	NM	NM	UT	UT	UT
							Navajo Nation				
								Ute Mountain Ute Tribe			

3 (EPA, 2016)

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Agricultural criteria for copper, lead, and manganese were exceeded for 132 kilometers downstream from GKM, including the Animas River through the town of Durango and the Southern Ute Indian Tribe reservation land. Criteria related to agriculture or irrigation were exceeded for arsenic, copper, lead, and manganese for several hours as far downstream as river kilometer 132. In downstream segments of the Animas River, water withdrawals for public water supply, irrigation, and agriculture were halted as an emergency spill response measure on August 6, 2015 (U.S. EPA, 2016). As previously stated, NMED accounts suggest that some intakes could not be successfully closed during this time period.

Commented [AL1]: Kate: these two sentences are quotes from the EPA fate and transport report- I'm not sure what the difference between the two is- is the second sentence inclusive of a different irrigation standard?

In addition to the plume information described above, a *Screening Level Human Health and Agricultural Risk Assessment* report commissioned by UDEQ describes exposure pathways associated with agriculture following the GKM event (Tetra Tech, 2018). The report characterizes the risks of metals from the GKM event entering the river, and subsequently being used for agricultural watering. Additional concerns included metal concentrations in the soil of fields that were irrigated with river water. As previously stated, the report found that "[b]ased on the evaluation of risks associated with direct human exposure to SJR water and sediment, agricultural exposure pathways, and potential accumulation of metals in soil, there are no immediate risks to human health or agricultural receptors" ([HYPERLINK "https://documents.deq.utah.gov/water-quality/watershed-protection/DWQ-2018-008831.pdf"] Tech, 2018).

NMSU performed a study published in December 2018 regarding the 2017 growing season. The report evaluated the potential for metals from the GKM event to be distributed to water, soils, and crops. To accomplish this, the study reviewed ditch sediment data, irrigation water samples, crop samples, and surface soil samples during the 2017-2018 growing season. As previously stated, the report found that agricultural crops in the watershed are not at risk (Jha et. al, 2018).

EPA collected sediment samples from irrigation ditches following the GKM event. While these ditches were likely closed before metals from GKM approached intake structures, data shows background metal levels in the irrigation ditches. Although the study was not repeated, these results suggest that the watershed's mining legacy has background effects on irrigation systems in the region.

Present ditch data here. Compare with sediment screening values.

Commented [AL2]: Analysis placeholder for Kate

Sub question: Can observed metal concentrations within the contaminant plume be correlated to irrigation intake locations as the plume moved down the watershed?

To correlate post-GKM event data with the location of agricultural intake structures, all identified intake structures were mapped on the Animas and San Juan Rivers and compared to post-GKM event monitoring locations. Following the GKM event, a monitoring program called the San Juan Monitoring Program (SJLTMP) was established. In most cases, the nearest upstream SJLTMP site was used as a proxy for intake structures. In cases where the nearest upstream SJLTMP site was many miles away but a downstream SJLTMP site was available in close proximity downstream, the downstream site was used if there were no tributaries or washes present between the two points.

*Figure [SEQ Figure * ARABIC] SJLTMP Sites by Agriculture Diversion*

Post-GKM Sampling Site	State	Number of Diversions Immediately Downstream	Applicable Screening Value
02SANJUANR07	Utah, Navajo Nation	3	tbd
10SANJUANR38	New Mexico, Navajo Nation	1	tbd
67SanJua096.3	New Mexico, Navajo Nation	1	tbd
66SanJua100.2	New Mexico, Navajo Nation	1	tbd
66Animas001.7	New Mexico	1	tbd
66Animas009.8	New Mexico	2	tbd
66Animas028.1	New Mexico	4	tbd
ADW-022	New Mexico	5	tbd
66Animas057.0	New Mexico	3	tbd
NAR 6	Southern Ute	1	tbd
AR 19-3	Colorado	4	tbd

Compare sites above (post GKM data) with short/long term agriculture screening values.

Commented [AL3]: Analysis placeholder for Kate: These are the SJLTMP sites that are the closest upstream location to active agriculture intakes. Do you think an analysis of this comparison or something similar would be useful for the report?

Question Two: How do metal concentrations during high-flow conditions compare to agricultural screening standards?

EPA's *Analysis of the Transport and Fate of Metals Released from the Gold King Mine in the Animas and San Juan River* Report showed that metals deposited in sediment in the Animas River remobilized during the spring 2016 runoff period (U.S. EPA, 2016). Metal concentrations in water and sediment returned to pre-GKM event concentrations after 2016 runoff. Data suggest that metals were flushed out of the river system during this event and distributed in Lake Powell (U.S. EPA, 2016). EPA conducted additional sampling during spring 2017 runoff, which showed metal concentrations at a record low (Sullivan et. al, 2018).

Analysis of 2016 run-off data and other data to screening standards

Commented [AL4]: Analysis placeholder for Kate

Sub question: Can metal concentrations during high-flow rates be paired with the locations of irrigation intakes to show what metal concentrations were observed in Spring 2016 runoff or other high-flow conditions?

High flow rates can also occur during the monsoon season, or as the result of a large storm event. During high-flow conditions, it is possible that deposited metals are redistributed and have the potential to enter irrigation systems. To demonstrate conditions at the irrigation diversions during high-flow conditions, the best available data are the SJLTMP sites closest to the irrigation diversions.

Compare site data from Figure 3. Site list with SJLTMP 2016, 2017, and monsoon 2018 events.

Commented [AL5]: Analysis placeholder for Kate

Question Three: What impact did GKM have on livestock through livestock watering?

Livestock watering is identified as an exposure pathway and is comprised of two elements; direct ingestion of water by livestock, and ingestion of irrigated plants by livestock. Because monitoring data suggest that the plume passed through the river system in a matter of hours, it is difficult to quantify the impact of the plume during this time period. Furthermore, irrigation diversions used for agricultural purposes are thought to have been closed immediately following the event, making direct ingestion of water unlikely.

Comparisons of livestock watering standards to plume conditions were performed as part of UDEQ's effort to relate screening values with the passage of the contaminant plume following the GKM event. No exceedances were observed as part of this study, as shown in Figure 10. These data suggest that no threat to livestock was created by the event, even if agricultural receptors were not closed immediately following the event.

Data also suggest that the second event that mobilized GKM metals was runoff occurring during the spring of 2016 (U.S. EPA, 2016).

Analysis of watering screening values with 2016 runoff data.

Commented [AL6]: Analysis placeholder for Kate

Ingestion of irrigated plants by livestock may present an exposure pathway if water used to irrigate plants was observed to exceed agricultural screening levels. Therefore, assessing the risk of livestock ingesting irrigated plants relies on whether agricultural screening levels exceedances were observed during the event. As previously discussed, agricultural exceedances were minimal and given the short duration of the exceedances, studies suggest that the San Juan River is safe for agriculture and irrigation (U.S. EPA, 2017).

Gold King Mine Event Summary

Commented [AL7]: Kate- This language will need to be adjusted if your analysis identifies any exceedances, or any other results different than stated here

Data collected by EPA, Utah, and New Mexico support a similar conclusion: metals mobilized by the GKM event were either rapidly transported downstream or entrained in sediment in the Animas and San Juan Rivers. The plume of metals induced by the GKM event created elevated levels of metals in the Animas River for periods up to 37.25 hours. These metals were then deposited in sediments, and the metal concentrations in the river returned to background levels. During spring 2016 runoff, the majority of remaining metals were distributed to Lake Powell. By 2017, record low levels of metals were observed during spring run-off, suggesting that GKM metals had passed through the river system (Sullivan et. al, 2018).

Most agricultural diversion intakes were closed as an emergency response measure, greatly reducing the chance that the plume could enter irrigation systems. If structures could not be closed, there is a chance that water exceeding agricultural screening levels was used for irrigation purposes for a short period of time. After the plume rapidly moved downstream, intakes were re-opened and ambient river water stabilized to background levels of metals.

High flow events have the potential to mobilize the relatively small quantity of residual GKM metals deposited in the river system. Results from sampling these high-flow events show XX.

Commented [AL8]: Analysis placeholder for Kate

The encouraging results of this analysis suggest that the GKM had a limited impact on irrigation systems, agriculture, and livestock. Screening level exceedances were short lived and occurred when intake structures were closed. Continued monitoring of run-off and monsoonal events is scheduled for 2019 and will provide more data to integrate with and further inform these conclusions.

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Conclusion

Studies performed from 2015 to 2018 in the watershed reached similar conclusions regarding the status of water quality for agricultural purposes: agriculture in the region is safe. In general, the watershed has long been characterized by high metal loadings, both from mining contributions in the Animas headwaters, uranium mining on the San Juan, and from natural geological sources throughout the watershed. Other impairments to water quality also exist regionally and include wastewater contributions, erosion, livestock, and eutrophication. While these factors are noteworthy, data shows they are not decreasing water quality below agricultural screening standards.

Groundwater quality used for irrigation purposes fluctuates seasonally and reflects the changes of metal loads in the watershed during spring run-off. Studies suggest that groundwater is generally safe for agricultural purposes, though groundwater monitoring in the watershed should continue.

Like all watersheds, many factors affect water quality and therefore influence agriculture in the San Juan watershed. While the watershed's past is relatively well understood, current monitoring efforts continue to help characterize the state of the watershed. Future monitoring efforts will provide additional water quality data that can be compared to agricultural screening levels to indicate if water from the rivers are safe for agricultural use.

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Appendix A

Summary of risk-based water quality standards (mg/l) for crops, livestock, and human health

Metal	Crops (this study)	U.S. EPA 1972 Criteria crops	Cattle (this study)	Sheep (this study)	U.S. EPA 1972 Criteria livestock	Human health – water ingestion	Human health – homegrown produce	Human health – homegrown meat
Aluminum	5	--	190	170	--	15	43000	8.64E+05
Antimony	0.5	--	1.8	1.6	--	0.006	0.37	5.79E+02
Arsenic	0.1	0.10	7.2	4.5	0.2	0.00002/0.0051	0.000026/1.41	4.83E-01
Barium	50	--	75	6.5	--	3	370	1.93E+06
Beryllium	0.1	--	2.8	2.5	--	0.03	37	2.90E+03
Cadmium	0.01	0.01	2.3	1.5	50	0.008	0.185	2.63E+03
Chromium	0.1	--	24	15	--	23	9200	3.95E+05
Cobalt	1	--	6	3.8	--	0.005	1.2	2.17E+01
Copper	0.2	0.2	9.8	2.2	0.5	1	4.4	5.79E+03
Iron	5	5	120	75	2.0	11	19500	5.07E+04
Lead	5	5	23	150	0.05	0.015	0.015	15
Manganese	0.2	--	490	300	--	--	77	5.07E+05
Mercury	0.03	--	0.45	0.3	--	0.005	0.042	1.74E+00
Molybdenum	0.01	--	1.2	0.75	--	0.075	2.3	1.21E+03
Nickel	0.2	0.2	24	15	--	0.3	9.25	4.83E+03
Selenium	0.02	--	1.2	0.75	--	0.075	5.5	4.83E+02
Silver	56	--	1100	1000	--	0.075	1.4	2.41E+03
Thallium	0.1	--	9	8	--	0.00015	0.69	3.62E-01
Vanadium	0.1	--	12	7.5	--	0.075	46	2.90E+03
Zinc	2	2.0	120	45	25.0	4.5	9.2	4.34E+03

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